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HERE'S HOW

Operation of the C-1 Autopilot



Aeronautical Division

MINNEAPOLIS-HONEYWELL

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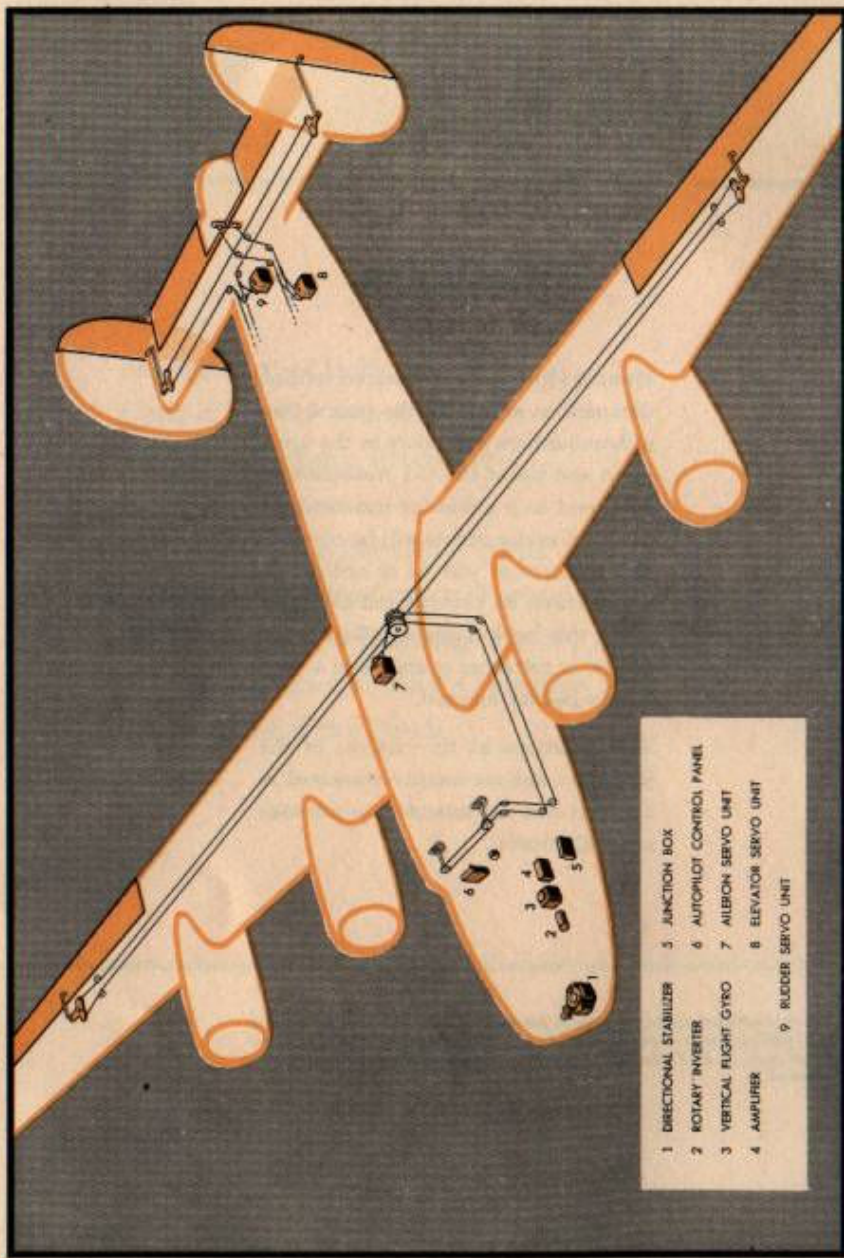
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FOREWORD

HERE'S HOW is an illustrated outline designed as an aid to the instruction of bombardiers and pilots in the operation and use of the C-1 Autopilot. If it is used as a guide for instructional work, all major points will be covered, and instruction will be co-ordinated. In addition, its brevity and clearness make this book a useful reference for review or refresher courses and a very handy pocket manual.

The questions at the bottom of the pages are not necessarily answered in the text but are intended to provoke class discussion.

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Arrangement of C-1 Autopilot Units in a B-24 Airplane



Arrangement of C-1 Autopilot Units in a B-17 Airplane

CONTROL UNITS OF THE C-1 AUTOPILOT

The Autopilot is made up of nine units: three servo units, a vertical flight gyro, a stabilizer (horizontal gyro) with attachments, the Autopilot control panel, an amplifier, a rotary inverter, and a junction box.

SERVO UNITS

The servo units drive the control surfaces by means of cables clamped to the regular control cables. The direction of control surface movement is controlled by electrically operated clutches between the electric motor and the cable drum of each unit.

Since the servos are installed near the surfaces which they control, the cables from servo to control surface are short and are therefore less affected by temperature changes and less likely to be damaged by gunfire than the long manual control cables.

DIRECTIONAL STABILIZER

The stabilizer, located in the nose of the airplane, contains the horizontal gyro which serves as a directional reference for the Autopilot. Attached to the side of the stabilizer is a directional panel which applies electrical signals to steer the airplane. The directional panel is connected to the stabilizer gyro through the Autopilot clutch. When the clutch is engaged, the stabilizer steers the airplane; when it is disengaged, the bombardier can steer the airplane manually. The pilot can engage and use the Autopilot in navigational flights without the assistance of the bombardier, provided the Autopilot clutch is engaged.



AILERON
SERVO UNIT



RUDDER
SERVO UNIT

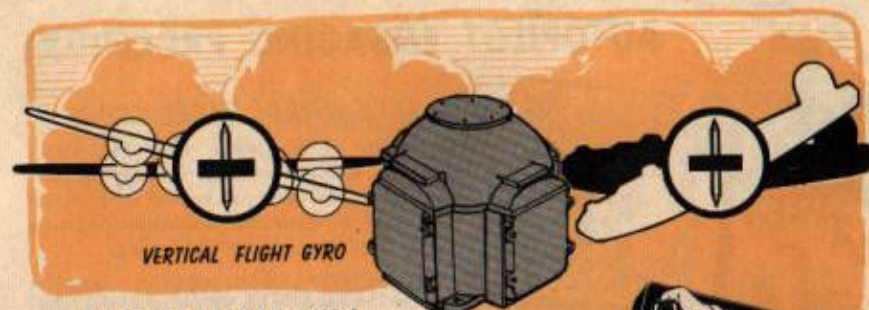


ELEVATOR
SERVO UNIT



DIRECTIONAL
STABILIZER

QUESTION: What part of the Autopilot is attached to the stabilizer for steering the airplane?



VERTICAL FLIGHT GYRO

VERTICAL FLIGHT GYRO

The vertical flight gyro controls the attitude of the airplane in the pitch and roll axes. When the Autopilot is engaged, the vertical flight gyro measures electrically any pitch or roll deviation of the airplane and produces signals which direct the servo units to correct the deviation.

AUTOPILOT CONTROL PANEL

The Autopilot control panel is used for engaging the Autopilot and adjusting its operation to compensate for changes in flight conditions. After the knobs are set, no further adjustments are needed unless flight conditions change. A turn control is provided which permits the pilot to make co-ordinated turns without disengaging the Autopilot.



AUTOPILOT
CONTROL PANEL

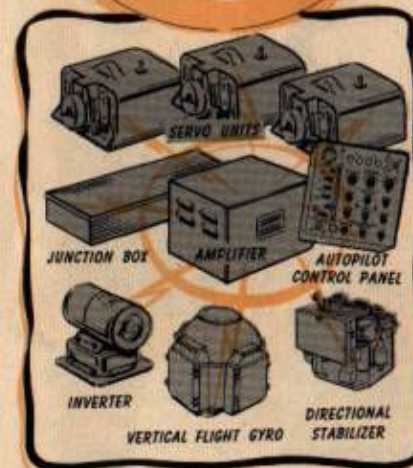


AMPLIFIER, INVERTER, J BOX

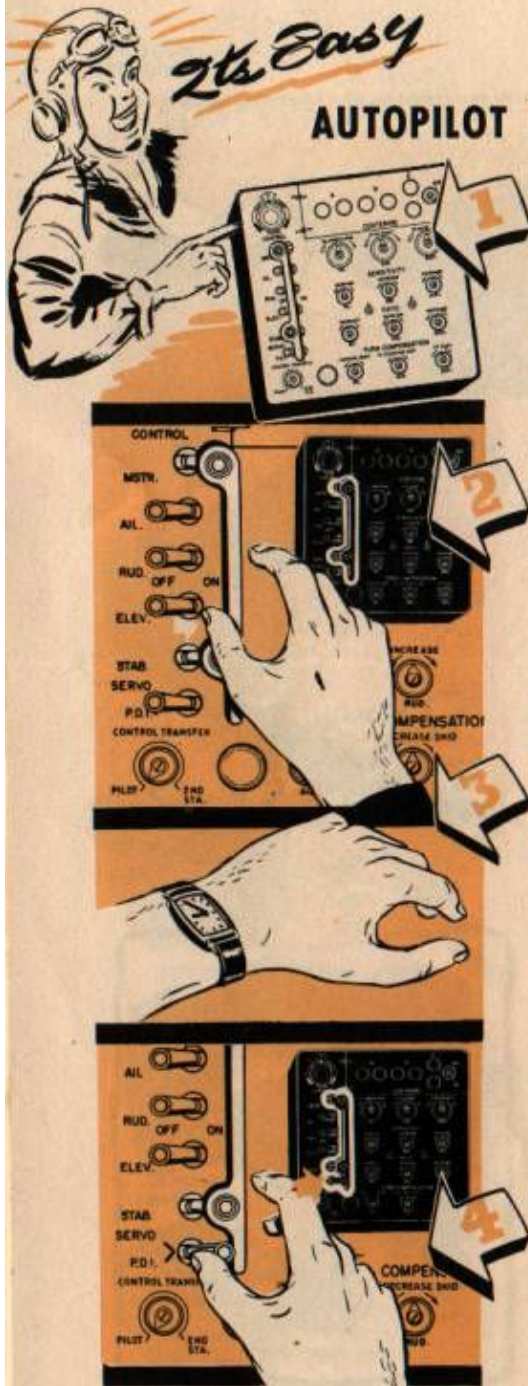
The amplifier controls the operation of the servo units, causing them to move the control surfaces of the airplane in one direction or the other, in response to corrective signals received from the gyros.

The rotary inverter converts direct current from the airplane's batteries into the alternating current required by the amplifier and the control units.

The junction box provides terminals for interconnecting the various wires of the circuit.



QUESTION: What unit supplies the signal to give up-elevator in all turns?



2nd Easy

AUTOPILOT ENGAGING PROCEDURE

RESTRICTED

SET CONTROL PANEL KNOBS

Unless it is known that the Autopilot control panel is already in correct adjustment, it is well to turn all knobs to their midpositions (pointers at 12 o'clock) before engaging.

Exceptions: The control transfer should be left at PILOT and the tell-tale-light shutter should be left ON.

TURN ON MASTER SWITCH

This switch starts all the electric motors of the Autopilot, except the torque motor in the stabilizer. The master switch should be turned on immediately after take-off so the units will be kept warm as cooler altitudes are reached. The Autopilot will not control the airplane until the AILERON, RUDDER, and ELEVATOR switches are turned on.

WAIT TEN MINUTES

A warm-up period is required after the master switch is turned on to allow the gyros in the stabilizer and vertical flight gyro to come up to speed. If subsequent engaging steps are taken too soon (while gyros are running slowly), the stabilizer gyro bearings may be damaged by the erratic precession which will occur when the torque motor is energized, or the Autopilot will not be properly centered because the vertical flight gyro had not erected fully. In cold weather, use heating covers according to instructions in T. O. 11-30-11.

TURN ON SERVO-PDI SWITCH

The SERVO-PDI switch controls two circuits: it connects the PDI meter on the instrument panel to the meter on the stabilizer, and it starts the torque motor which opposes any force tending to precess the stabilizer gyro.



5

MANUALLY TRIM AIRPLANE FOR STRAIGHT-AND-LEVEL FLIGHT ... CHECK WITH INSTRUMENTS

The gyro horizon, turn-and-bank indicator, and sensitive altimeter or rate-of-climb indicator denote the airplane's attitude more accurately than the average pilot can judge by observation.

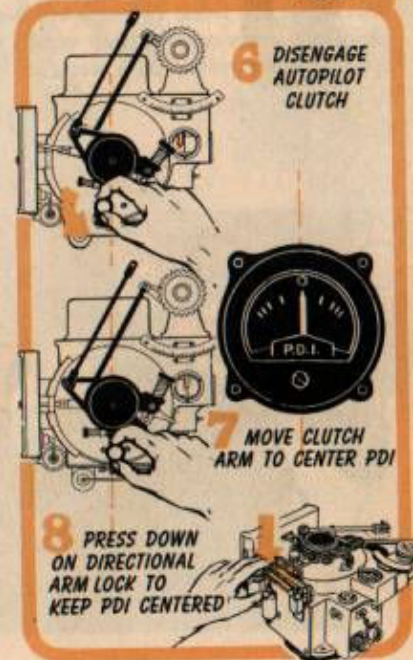
If the airplane is not carefully trimmed before the Autopilot is engaged, the Autopilot will have to fight the trim tabs and its operation will not be uniform.



DISENGAGE AUTOPILOT CLUTCH AND CENTER PDI

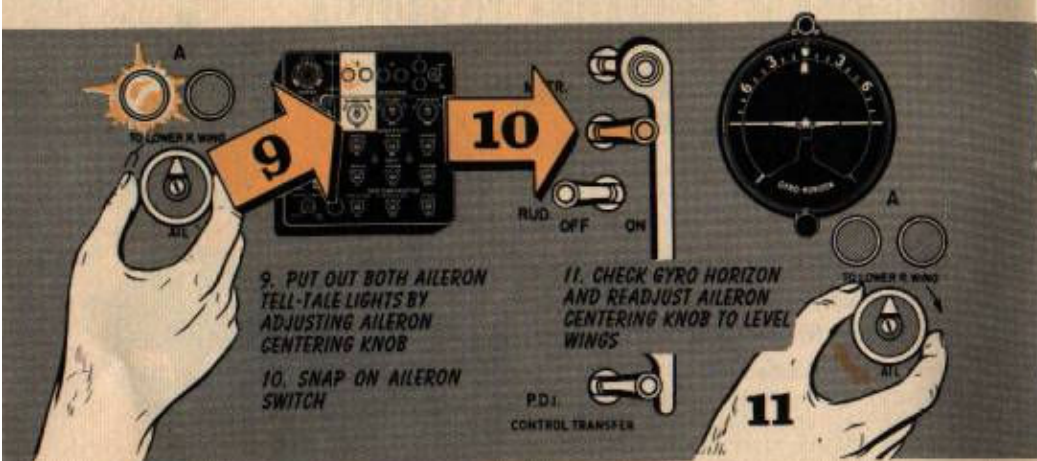
With the airplane flying straight and level, disengage the Autopilot clutch by turning the knob counter-clockwise. Then center PDI by moving the Autopilot clutch arm to the center of its travel. Making sure the PDI needle is *exactly* centered, press down on the directional arm lock to hold the clutch arm in position while the pilot continues his engaging procedure.

Alternate Method: If crew does not include a bombardier, leave the Autopilot clutch engaged, and center PDI by turning the airplane in the direction of the PDI needle; then hold zero PDI course while engaging the Autopilot.

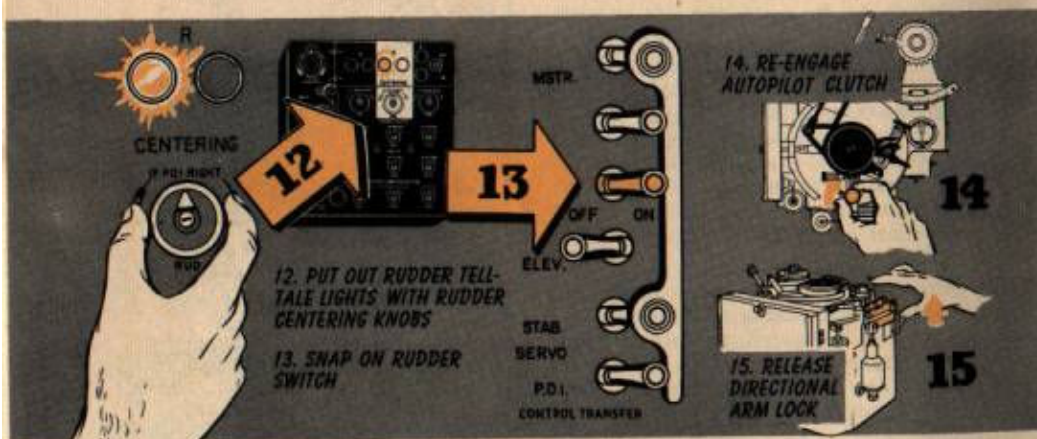


QUESTION: When a tell-tale light is on, does it indicate that the servo unit is moving the control surface?

RESTRICTED



Before the rudder servo is similarly engaged, the gyro horizon should be checked and aileron centering readjusted, if necessary, to make sure the wings are level. If wings are not level when rudder is centered and engaged, cross-control may result, as the Autopilot will apply rudder to hold the airplane on a straight course.



QUESTION: What switch must be disengaged when the pilot wishes to fly on Autopilot but maintain altitude manually?

16. READJUST RUDDER CENTERING KNOB TO CENTER PDI

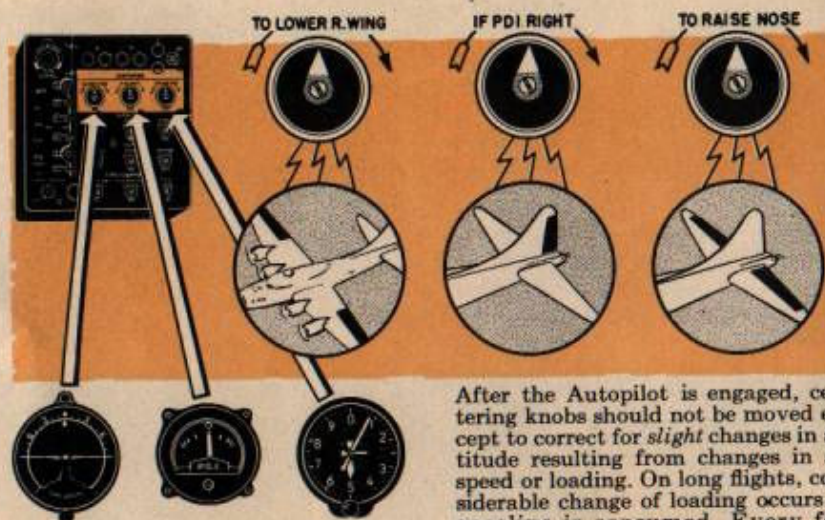
After the pilot has engaged both rudder and aileron servos, and the bombardier has released the directional arm lock and re-engaged the Autopilot clutch, the pilot should readjust rudder centering to zero PDI if necessary.

Likewise, after extinguishing the elevator lights and engaging the elevator switch, he may readjust elevator centering if the rate-of-climb indicator or sensitive altimeter indicates a gain or loss of altitude.



QUESTION: Why is it wrong and sometimes dangerous to change the manual trim tabs while the Autopilot is still engaged?

CENTERING



The **CENTERING** knobs are the trim tabs of the Autopilot.

After the Autopilot is engaged, centering knobs should not be moved except to correct for *slight* changes in attitude resulting from changes in air speed or loading. On long flights, considerable change of loading occurs as gasoline is consumed. Every few hours, therefore, the Autopilot should be *disengaged* and the airplane *re-trimmed manually* before re-engaging.

SENSITIVITY

The **SENSITIVITY** knobs are used to regulate the amount of airplane deviation the Autopilot will allow before it applies correction. High sensitivity, therefore, provides maximum flight stability, but it is possible to adjust sensitivity so high that the controls will vibrate or "chatter."

To adjust sensitivity, turn knobs clockwise until controls chatter; then back off until continuous chatter stops.

SENSITIVITY TOO LOW—Autopilot reacts like a *sleepy* human pilot, allowing plane to wander.

CORRECT SENSITIVITY—Autopilot corrects even slight deviations, like an *alert* pilot.

SENSITIVITY TOO HIGH—Autopilot acts like a *human* pilot with the D. T.'s.



QUESTION: How can the airplane be correctly trimmed while the Autopilot is engaged?

RATIO



The **RATIO** knobs regulate the amount of control movement applied to correct a given deviation.

To adjust ratio, set pointers up, then adjust to give quick recovery without hunting. Observe wing tips, horizon, and PDI for evidence of plane hunt. If hunting exists, reduce the ratio in the corresponding axis.

Ratio will require slight readjustment with any appreciable change of indicated air speed. Following any change of ratio, recheck centering.

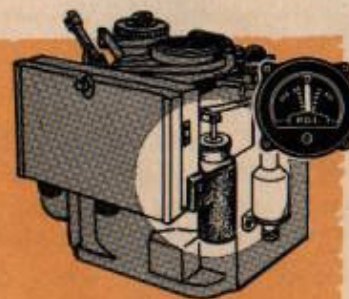
LOW RATIO—produces small control surface movements and slow recovery.

CORRECT RATIO—produces quick recovery without overshooting.

HIGH RATIO—produces excess control surface movement resulting in a "ship hunt".



DASHPOT



Dashpot adjustment affects the ability of the Autopilot to hold PDI.

The **DASHPOT** is a small oil-filled cylinder in which movements of a plunger are damped by the oil. Its purpose is to produce an increased initial reaction of the rudder, simulating the "rudder kick" which a human pilot uses in correcting a sudden deviation in the turn axis.

If the dashpot is set too loose, PDI will waver with irregular movements; if it is set too tight, the airplane will hunt in the turn axis, as indicated by a periodic oscillation of PDI.

To adjust the dashpot:



1. Unlock adjusting nut by turning lock ring counter-clockwise.
2. Turn knurled adjusting nut UP to loosen or DOWN to tighten, according to the correction needed.
3. Turn lock ring clockwise to hold adjusting nut.

QUESTION: What adjustment other than those on the ACP affects rudder operation?

CO-ORDINATING BOMBARDIER'S TURNS



1. BE SURE AIRPLANE IS FLYING STRAIGHT AND LEVEL WITH PDI ON ZERO

Check airplane's attitude with instruments, and adjust with centering knobs if necessary.

2. DISENGAGE THE AUTOPILOT CLUTCH

Turn clutch knob counter clockwise.

3. MOVE DIRECTIONAL ARM TO EXTREME RIGHT OR EXTREME LEFT

Move slowly and in direction as if swinging the tail of the airplane. Hold arm against stop.

NOTE

If the stabilizer is equipped with a bombardier's turn knob, this knob may be used to move the clutch arm after disengaging the Autopilot clutch. Be sure the 12-degree stops are not in use when adjusting turn coordination.



4. ADJUST TURN COMPENSATION KNOBS



INCREASE BANK



AIL

Set bank trimmer to give an 18° bank.



TO DECREASE SKID



RUD

Set skid trimmer to center ball.



UP ELEV.



ELEV

Set up-elevator trimmer to maintain altitude.



5. ENGAGE AUTOPILOT CLUTCH AND ALLOW STABILIZER TO RE-CENTER PDI

Speed of automatic PDI recovery affords a good check on aileron ratio setting.

If PDI recovery is slow decrease aileron ratio setting. If PDI recovers so fast it overshoots, increase aileron ratio setting.



CO-ORDINATING TURN-



1. BE SURE AIRPLANE IS FLYING STRAIGHT-AND-LEVEL WITH PDI ON ZERO BEFORE STARTING TURN.

Check with instruments and trim airplane with centering knobs if correction is needed.

2. MOVE TURN CONTROL TO FIRST STOP

Turn knob for either right or left turn and stop at edge of shaded area.

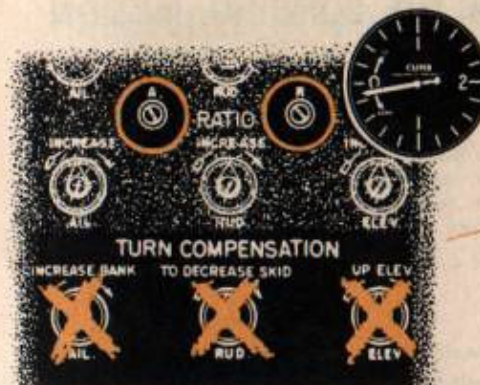
3. ADJUST AILERON TURN CONTROL TRIMMER "A" TO GIVE 30° BANK

Make adjustments with a screwdriver and check degree of bank on the gyro horizon.

4. ADJUST RUDDER TURN CONTROL TRIMMER "R" TO ELIMINATE SKID

Check co-ordination with turn and bank indicator.

CONTROL TURNS



NOTE

If the up-elevator trimmer has been adjusted for bombardier's turns, it will also maintain altitude in turn-control banks up to 18 degrees, provided air speed is maintained. If loss of altitude occurs in a turn-control turn, it can be corrected by adjusting elevator centering, and then readjusting centering for straight-and-level flight after the turn has been completed.



5. COMING OUT OF TURN, STOP POINTER AT ZERO

Leave knob in this position until wings are level.



6. WHEN WINGS ARE LEVEL, RETURN POINTER TO CENTER

If pointer is turned to center before wings are level, recovery will not be smooth.



7. CAUTION: USE THE SHADED AREA AT THE EXTREME LOWER RANGE OF THE TURN CONTROL IN SMOOTH AIR ONLY

Turning the knob into this range produces banks in excess of 30 degrees, which, in rough air, might upset the vertical flight gyro.

QUESTION: Do the adjustments used for co-ordinating a turn-control turn affect the co-ordination of a bombardier's turn?

QUESTION: What happens if the turn control is turned while the bombardier is making a turn?

SETTING UP THE AUTOPILOT FOR THE BOMBING MISSION

SIMULATE BOMBING CONDITIONS

With master switch and PDI switch ON but other engaging switches OFF, open bomb bay doors. Select and hold bombing airspeed and altitude.

MANUALLY TRIM THE AIRPLANE

Set trim tabs accurately for straight-and-level flight. Check gyro horizon, turn-and-bank indicator, and rate-of-climb indicator to make sure of the airplane's attitude.

ENGAGE AND ADJUST THE AUTOPILOT

Center PDI and engage Autopilot. Then make adjustments for accurate flight control and co-ordinate bombardier's turns according to instructions on pages 7-11.

DOUBLE-CHECK THOSE ADJUSTMENTS WHICH AFFECT PDI

Since the ability of the Autopilot to hold PDI is extremely vital to the success of the mission, recheck the adjustments of sensitivity, ratio and dashpot. Note, in particular the speed of automatic PDI recovery as a check on aileron ratio. (See page 13.)

OPERATION OF STABILIZER CLUTCHES IN BOMBING

WHEN THE BOMBARDIER STEERS THE AIRPLANE

Both clutches disengaged

When the bombardier is flying evasive action or selecting the target heading he has both clutches disengaged and steers the airplane either by turning the bombsight or by moving the Autopilot clutch arm.

WHEN THE BOMBSIGHT STEERS THE AIRPLANE

Bombsight clutch engaged; Autopilot clutch disengaged

With the bombsight clutch engaged the stabilizer holds the sight on a fixed heading. The Autopilot clutch must be disengaged so that the bombsight can control the airplane's flight.

WHEN THE PILOT HAS FULL CONTROL

Autopilot clutch engaged; bombsight clutch disengaged.

Whenever returning full control to the pilot it is important to engage the Autopilot clutch before disengaging the bombsight clutch if the sight has been adjusted.

MALADJUSTMENTS AND

1. PDI CENTERED, BALL NOT CENTERED, IN STRAIGHT FLIGHT

This condition is caused by improper trimming, or centering with one wing low and opposite rudder applied to keep the airplane from turning. If this happens when flying on Autopilot:

- Readjust aileron and rudder centering,
- or
- Disengage both rudder and aileron switches;
- Disengage Autopilot clutch and recenter PDI;
- Adjust centering and re-engage rudder and aileron switches.

2. BALL CENTERED, BUT PDI OFF

Correct by one of the following steps:

- Readjust rudder centering,
- or
- Disengage both rudder and aileron switches;
- Disengage Autopilot clutch and recenter PDI;
- Adjust centering and re-engage rudder and aileron switches.

3. PLANE HUNTS IN RUDDER AXIS, AND PDI WAVERS

This is caused by improper setting of ratio or dashpot. To correct:

- Loosen locking collar and unscrew dashpot slowly. Stop at the point where hunting ceases, and relock.
- If loosening the dashpot does not eliminate the rudder hunt, reduce rudder ratio. After changing the ratio, check rudder centering and the skid trimmer adjustments; then tighten dashpot to a setting just above that which produces a hunt.

THEIR CORRECTION

4. TURNS CO-ORDINATED IN ONE DIRECTION, BUT NOT IN THE OTHER

Plane not properly trimmed before starting turns.

- To correct, return to level flight and readjust aileron and rudder centering, or
- Disengage rudder and aileron switches, retrim manually, then re-center PDI before re-engaging.

5. PLANE SKIDS WHEN TURNING ONE DIRECTION AND SLIPS WHEN TURNING THE OTHER DIRECTION

Disengage Autopilot and check manual trim of airplane; then recenter and re-engage.

6. HUNTING IN A TURN, AND NOT IN STRAIGHT-AND-LEVEL FLIGHT

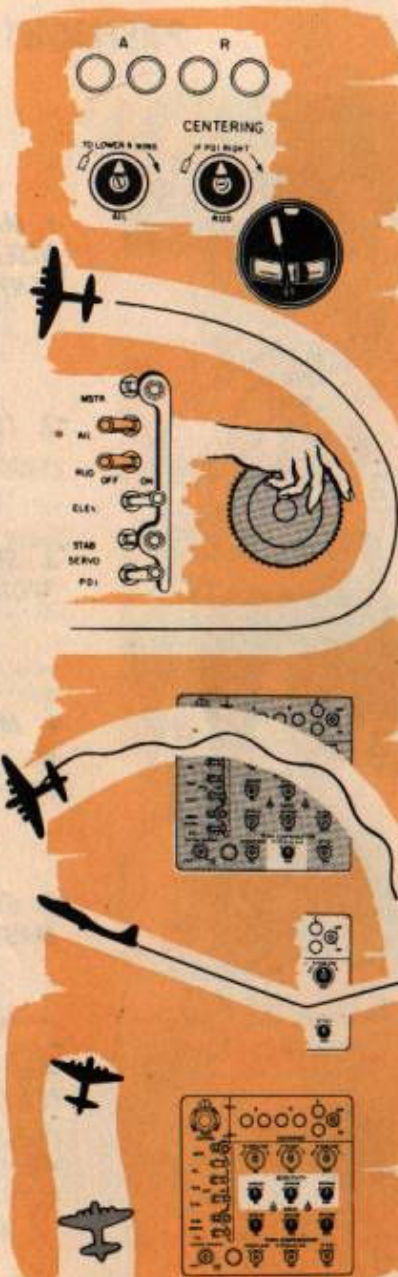
Readjust skid trimmer until hunt ceases, even if necessary to introduce a slight skid.

7. LOSS OR GAIN OF ALTITUDE

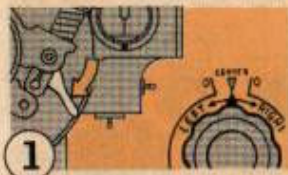
- In straight-and-level flight, correct by using the elevator centering knob.
- In bombardier's turn, adjust up-elevator trimmer (elevator compensation) and increase elevator ratio. In a bombing run, maintain altitude by use of elevator centering knob.

8. PLANE WALLOWS OR LACKS STABILITY

For a condition of general lack of stability (not a hunt), increase sensitivity adjustments. Also inspect cable tensions, as loose control cables are a common cause of sloppy aileron action. Since the rudder and elevator servos are near the surfaces which they control, less cable trouble is encountered on these two axes.



PREFLIGHT INSPECTION



1. MAKE SURE BOMBSIGHT CLUTCH IS DISENGAGED AND TURN CONTROL IS CENTERED



2. TURN ON MASTER SWITCH

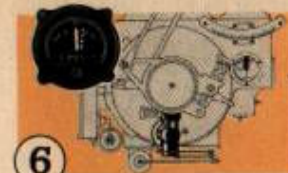


3. SET ALL ADJUSTING KNOBS ON ACP TO "POINTERS UP" POSITION



4. MAKE SURE POINTERS ARE NOT LOOSE

If a pointer is loose, set it to point upward at the center of the knob's range.



5. FIVE MINUTES AFTER TURNING ON MASTER SWITCH, TURN ON PDI SWITCH

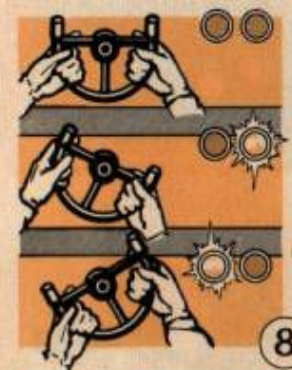
6. DISENGAGE AUTOPILOT CLUTCH AND CENTER PDI; THEN RE-ENGAGE CLUTCH

Observe that PDI meter on instrument panel also moves to center.



7. MANUALLY OPERATE AIRPLANE CONTROLS THROUGH THEIR FULL RANGE OF TRAVEL

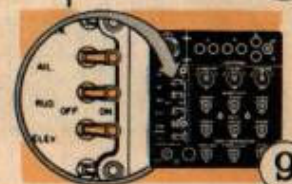
Repeat several times, as this moves the servo pot wipers across the pot windings and tends to clean off dust or dirt and insure good electrical contact. Make sure that controls move freely.



8. OBSERVE ACTION OF TELL-TALE LIGHTS AS MANUAL CONTROLS ARE MOVED

When controls are in center position, lights should go off. At all other positions, one light or the other should remain on steadily. If the lights flicker at off-center control positions, the corresponding servo pot requires cleaning.

EXCEPTION: On some airplanes balance pot wiper may run off winding at extremes of control range causing both lights to go out.



9. WITHOUT CENTERING, ENGAGE AILERON, RUDDER, AND ELEVATOR SWITCHES

If one light is on when switch is engaged, it will go out as the controls reach center position.



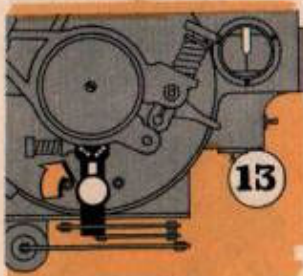
10. TURN EACH CENTERING KNOB SLOWLY THROUGH ITS FULL RANGE

Observe manual controls for correct direction of movement. Only one control surface should move in response to each centering knob. Controls should move in small even steps, one step each time light flashes.



11. DISENGAGE AUTOPILOT CLUTCH AND MOVE CLUTCH ARM TO EXTREME LEFT

Be sure it moves freely without binding. Aileron wheel should turn to the right, and the right rudder pedal should move forward.



12. MOVE AUTOPILOT CLUTCH ARM TO THE EXTREME RIGHT

The wheel should turn to the left, and the left rudder pedal should move forward.

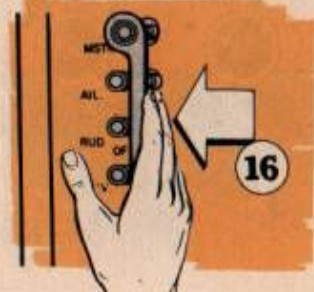


13. RETURN CLUTCH ARM TO CENTER, AND RE-ENGAGE AUTOPILOT CLUTCH

Check clutch tension. It should be necessary to apply considerable force to slip clutch.

14. ROTATE THE PILOT'S TURN-CONTROL KNOB FOR A 30° RIGHT BANK

The wheel should turn to the right, and the right rudder pedal should move forward.



15. REVERSE TURN CONTROL, CHECKING CONTROL MOVEMENT FOR LEFT BANK

The wheel should turn to the left, and the left rudder pedal should move forward.

NOTES

PREFLIGHT INSPECTION —

NOTES